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Performance Characteristics of a Parabolic and a Conical Underwater Acoustic Reflector

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ABSTRACT

The beam patterns of a parabolic and a conical underwater acoustic reflector of comparable size, using the same source transducer, showed the paraboloid to exhibit superior performance.

Relatively soft foam-rubber backing appears suitable for depths to at least 90 ft.

Use of secondary reflectors, i.e., front disk baffles to reduce side lobes, was found to have little or no beneficial effect on either the cone or the paraboloid performance.

Results of experimentation with the paraboloid indicated an optimum point at which acoustic performance and physical size became a tradeoff.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

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PERFORMANCE CHARACTERISTICS OF A PARABOLIC AND A CONICAL UNDERWATER ACOUSTIC REFLECTOR

INTRODUCTION

This report presents performance data obtained from a parabolic and a conical reflector designed for use with a 3-kHz cylindrical ceramic transducer of approximately 3/4-λ diameter. The objective was to obtain a narrow conical beam with good side-lobe suppression. Since the source was to be used in a water depth of approximately 100 ft, consideration had to be given to the physical size of the reflector as well as the beam pattern.

PARABOLIC REFLECTOR

A paraboloid of revolution with a focal length of 16-2/3 in. was chosen so that the mounting flange of the transducer would be affixed to a mounting flange at the apex of the paraboloid as shown in Fig. 1. This would place the center of the ceramic element of the transducer on the focus of the paraboloid. For experimental convenience the paraboloid was constructed to allow for an aperture ranging from 8 to 11 ft. Figure 2 is a scale drawing of a section of the paraboloid. Note the radial lines emanating from the focus. These angles, measured to the vertical, intersect the paraboloid at 20, 25, 30, and 34 degrees; these intersections denote the test stages in which foam-rubber backing material was peeled back from the periphery of the reflector. In addition, Fig. 2 shows positions in front of the transducer in terms of wavelengths at 3 kHz at which secondary disk reflectors or baffles were placed to determine their effect on reducing side-lobe emanation. Results from previous work* indicated that an incident acoustic ray would strike the baffle, reflect back against the primary reflector, and propagate in a more cohesive pattern. Figure 3 shows the source assembly with the reflector peeled back to the 30-degree position with a 20-in.-diameter baffle spaced 15 in. from the ceramic centroid.

With these physical variables, i.e., the reflector aperture, the baffle diameter, and the baffle distance from the ceramic centroid, beam pattern tests were conducted across the bandwidth of the transducer. The test depth was 50 ft. The pulse technique was used to obtain beam patterns. The source was slowly rotated about its ceramic centroid in a horizontal plane, the accuracy of which was checked with level and cross-level inclinometers.

Closed-cell natural foam rubber of 1-in. thickness was used for the rubber backing material. At a depth of 50 ft in water, this rubber compresses to one-half its original thickness. It is interesting to note that in an isolated test, at a depth of 90 ft, using the same reflector configuration, the beam pattern was practically identical to the pattern at the 50-ft depth even though the rubber had been further compressed by the hydrostatic pressure. Front-to-back ratios for all tests averaged about 35 to 40 dB.

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*W.J. Toulis, "Directional Transducer-Reflector Combination at Audio Frequencies," Journal of Underwater Acoustics 6 (No. 3):240 (1956).

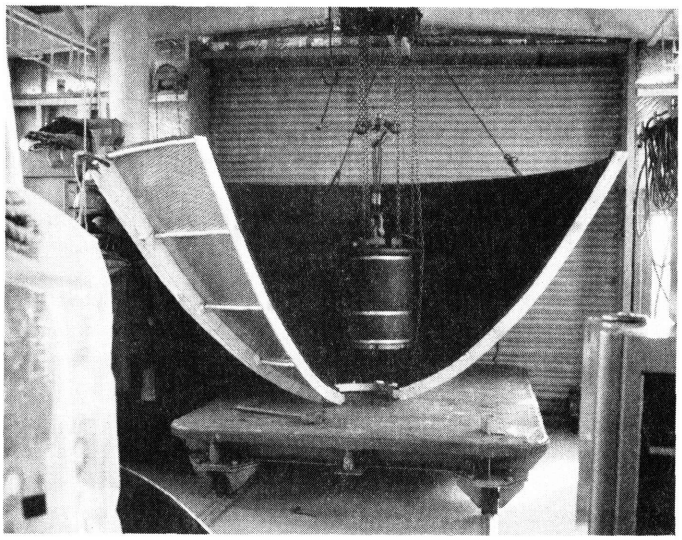

Fig. 1 - The 3-kHz, 3/4-λ-diameter ceramic transducer and the parabolic-reflector assembly

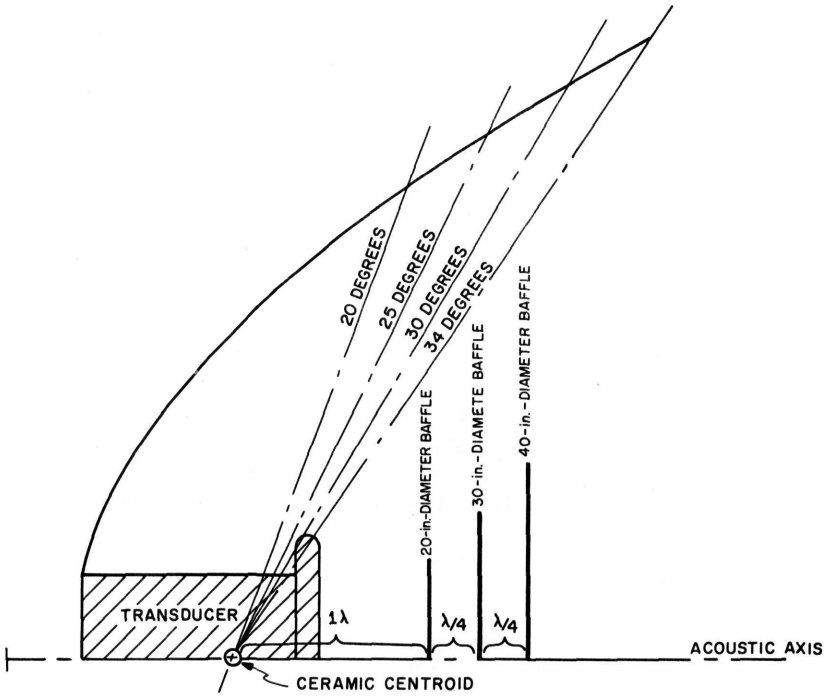

Fig. 2 - Half-section profile of the transducer and the parabolic-reflector assembly

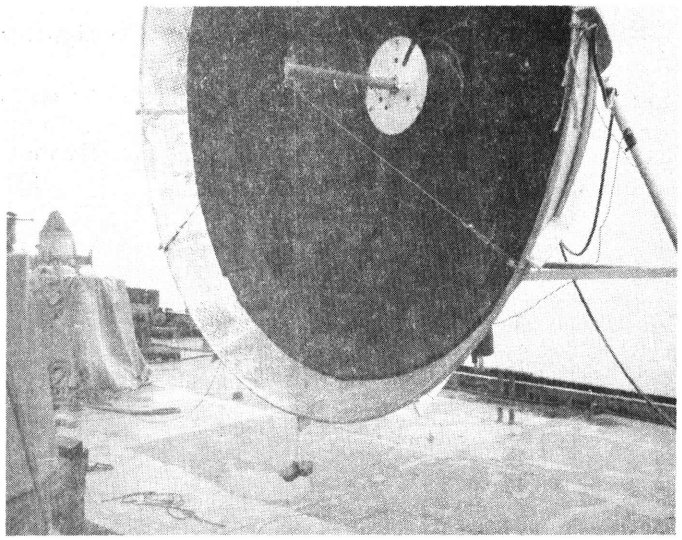

Fig. 3 - Parabolic reflector peeled back to 30 degrees with a 20-in.-diameter front baffle

Table 1 shows that the use of a baffle at any of the distances and diameters selected generally did not improve side-lobe reduction. However, Table 1 shows that the 34-degree aperture significantly improved the acoustic pattern over the smaller apertures but appears to be about the maximum worthwhile aperture size. Figure 4 shows this aperture effect for the cases where no baffle was used.

CONICAL REFLECTOR

A conical reflector has an advantage over a curved reflector in that it is less expensive to build. In addition, since the paraboloid had a transducer which was a large source rather than a small or point source, it was thought that perhaps the conical reflector would perform at least as well. A conical reflector of about the same aperture as the parabolic dish was built and tested using the same 3-kHz acoustic source. Figure 5 shows a half cross section of the assembly. The walls of the dish form a 45-degree angle with the acoustic axis so that any ray emanating radially outward from the transducer would strike the reflector at 45 degrees and presumably travel parallel to the acoustic axis. A theoretical ray diagram would show this ray to be in phase with any other ray which might emanate radially outward from the transducer.

Since conical reflectors do not have focal points, it was decided to move the transducer outward from the apex in two stages—$\lambda/2$ at 3 kHz in each stage as shown in Fig. 5. Baffles were used in front of the transducer (as in the case of the paraboloid) and behind the transducer. Figure 6 shows the conical dish with the two baffles. The transducer is in position 2 with the front 30-in.-diameter baffle spaced at $\lambda/2$. Unlike the previous tests of the paraboloid, the rubber backing was not peeled back in stages to reduce the aperture.

Table 2 shows data obtained at 2.4, 3, and 3.6 kHz for the three transducer mounting positions. As in the case of the paraboloid, use of a front baffle does not generally improve

Table 1
Performance Data for Paraboloid Reflector Configurations

Frequency (kHz)	Paraboloid Configuration (degrees)	Baffle Diameter (in.)	Spacing Baffle to Centroid (in.)	Main Beamwidth (degrees)	Av First Side-Lobe Reduction (dB)	Directivity Index
2.4	34	None	–	12	18	23.2
3	34	None	–	10	17	24.8
3.6	34	None	–	8.5	18	25.3
2.4	34	5	30	12	18	–
3	34	5	30	10	17	–
3.6	34	5	30	8.5	18	–
2.4	34	10	30	11.5	17.5	–
3	34	10	30	9.5	17.5	–
3.6	34	10	30	8	18.5	–
2.4	34	15	30	11	16.5	–
3	34	15	30	9.5	17.5	–
3.6	34	15	30	8.5	19	–
2.4	34	20	10	14	16	–
3	34	20	10	9.5	14	–
3.6	34	20	10	9	18	–
2.4	34	20	20	10.5	15	–
3	34	20	20	9.5	17	–
3.6	34	20	20	6.5	19.5	–
2.4	34	20	30	11	15.5	–
3	34	20	30	9	16.5	–
3.6	34	20	30	8	19	–
2.4	34	30	10	12.5	13	–
3	34	30	10	11	12.5	–
3.6	34	30	10	9	14.5	–
2.4	34	30	20	11.5	13.5	–
3	34	30	20	7.5	13.5	–
3.6	34	30	20	6.5	13	–
2.4	34	30	30	11	12.5	–
3	34	30	30	9	13	–
3.6	34	30	30	7.5	14	–
2.4	34	40	10	11.5	13.5	–
3	34	40	10	10.5	10.5	–
3.6	34	40	10	11	10	–
2.4	34	40	20	11	13	–
3	34	40	20	9	12	–
3.6	34	40	20	7	11.5	–
2.4	34	40	30	11	11	–
3	34	40	30	8.5	11.5	–
3.6	34	40	30	7	12	–
2.4	30	None	–	12	17.5	22.5
3	30	None	–	10.5	17	23.8
3.6	30	None	–	9.5	18	25.3

(Table 1 continues)

Table 1 (Continued)
Performance Data for Paraboloid Reflector Configurations

Frequency (kHz)	Paraboloid Configuration (degrees)	Baffle Diameter (in.)	Spacing Baffle to Centroid (in.)	Main Beamwidth (degrees)	Av First Side-Lobe Reduction (dB)	Directivity Index
3	30	20	10	10	14.5	–
3	30	20	15	9.5	16	–
3	30	20	20	10	15.5	–
3	30	20	25	10	15	–
3	30	20	30	10	15	–
3	30	20				–
2.4	25	None	–	13	17	–
3	25	None	–	10.5	15	23.1
3.6	25	None	–	10	15.5	–
3	25	20	10	11	14	–
3	25	20	15	11	15	–
3	25	20	20	11	14.5	–
3	25	20	25	11	15	–
2.4	25	30	10	12.5	13.5	–
3	25	30	10	11	13	–
3.6	25	30	10	9	13.5	–
2.4	25	30	20	14	11	–
3	25	30	20	10.5	12	–
3.6	25	30	20	9	13.5	–
2.4	25	40	10	15	11.5	–
3	25	40	10	11.5	11.5	–
3.6	25	40	10	10.5	11	–
2.4	25	40	30	12.5	10	–
3	25	40	30	11.5	10	–
3.6	25	40	30	9	11.5	–
2.4	20	None	30	15	16	20.5
3	20	None	30	12	15	22.0
3.6	20	None	30	9.5	15	24.0
2.4	20	30	18	14.5	16	–
3	20	30	18	12	15	–
3.6	20	30	18	10	15.5	–
2.4	20	40	18	13	9.5	–
3	20	40	18	10	10	–
3.6	20	40	18	8.5	10	–
			90' Depth			
2.4	20	None	90' Depth	17	16	19.9
3	20	None	90' Depth	12	15.5	21.9
3.6	20	None	90' Depth	9.5	15	24.5

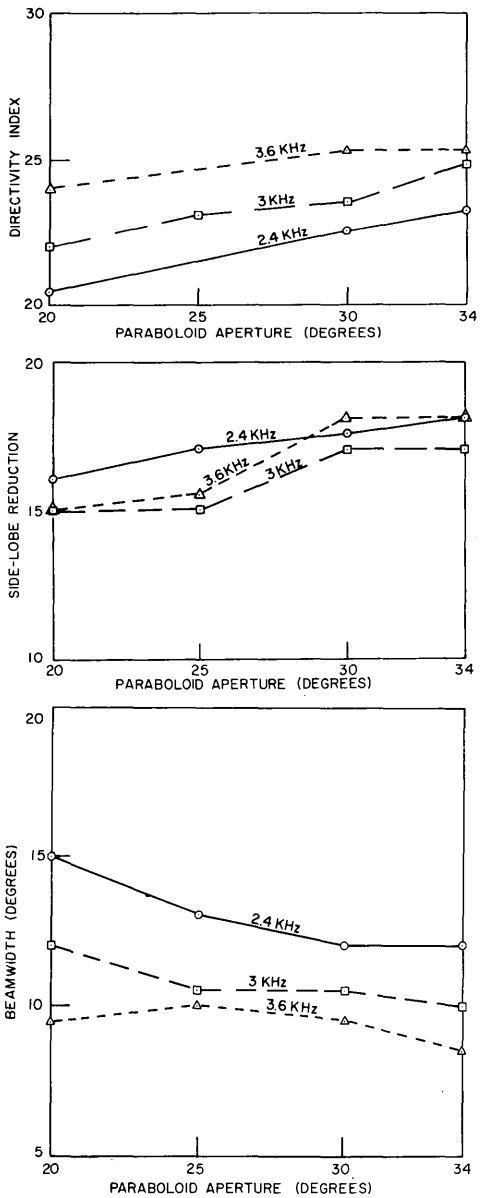

Fig. 4 - Parabolic aperture effect on directivity, side-lobe reduction, and beamwidth for the source paraboloid using no baffles

source performance. Figure 7, which compares transducer performance at the three mounting positions, shows that by mounting the transducer close to the apex, side-lobe reduction is greatest, but the beam narrows appreciably as the transducer is moved outward.

A comparison of the two reflector assemblies shows the paraboloid to be superior in that side-lobe reduction is greatly improved even though the beamwidth of the cone in some cases is as narrow as that of the paraboloid.

SUMMARY

Limited experiments with parabolic and conical underwater acoustic reflectors of comparable size, using a relatively large source transducer, has shown the paraboloid to have superior performance.

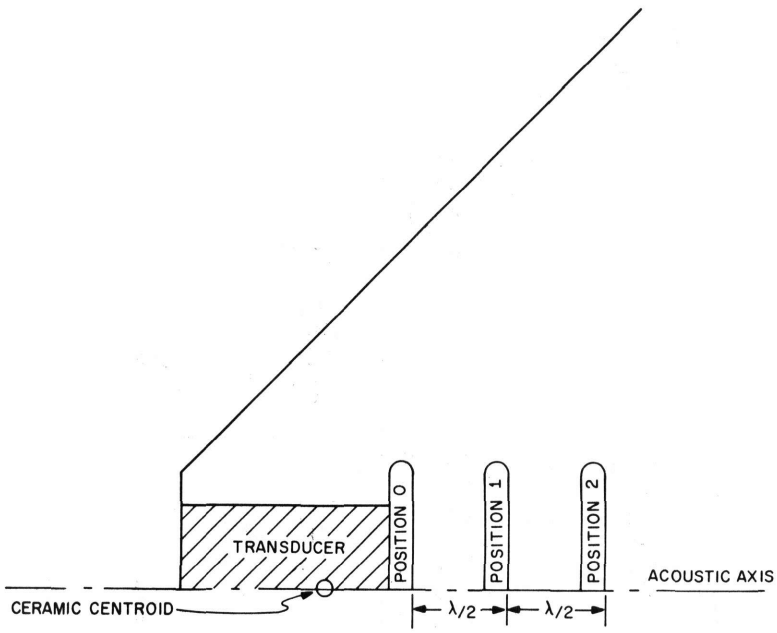

Fig. 5 - Half-section profile of transducer, 45-degree reflector assembly showing the three transducer mounting positions.

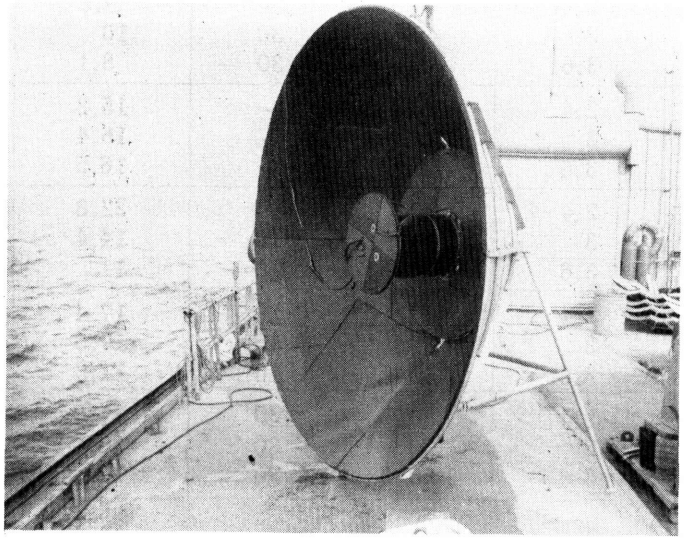

Fig. 6 - Transducer-conical reflector assembly

Table 2
Performance Data for Conical Reflector Configurations

Cone Configuration Position	Frequency (kHz)	Baffle Diameter (in.)	Baffle Spacing to Centroid (in.)	Main Beamwidth (in.)	Av First Side-Lobe Reduction (dB)
1	2.4	None	–	12.2	13
1	3	None	–	11.5	10.6
1	3.6	None	–	9.2	10.2
1	2.4	30	10	14	11.4
1	3	30	10	11.2	11.9
1	3.6	30	10	10.4	12.1
1	2.4	30	20	13	12
1	3	30	20	11.5	10.8
1	3.6	30	20	7.7	12
1	2.4	40	10	13	12
1	3	40	10	11.5	10.8
1	3.6	40	10	7.7	12
2	2.4	None	–	9.8	10.6
2	3	None	–	8	8.3
2	3.6	None	–	6.8	9.4
2	2.4	30	10	11.5	11.6
2	3	30	10	9	10.3
2	3.6	30	10	7	9.7
2	2.4	40	10	10	10.7
2	3	40	10	8	10.8
2	3.6	40	10	7	10.3
2	2.4	40	30	8.6	12
2	3	40	30	10	9.5
2	3.6	40	30	8.1	10
0	2.4	None	–	15.2	15.2
0	3	None	–	16.4	11
0	3.6	None	–	16.5	8.1
0	2.4	20	10	22.8	12.3
0	3	20	10	14.4	12.1
0	3.6	20	10	11	11.9
0	2.4	30	10	17.4	12.7
0	3	30	10	17.5	9.5
0	3.6	30	10	11.8	11.9
0	2.4	30	30	11.6	7
0	3	30	30	16.4	5.6
0	3.6	30	30	14	5.5

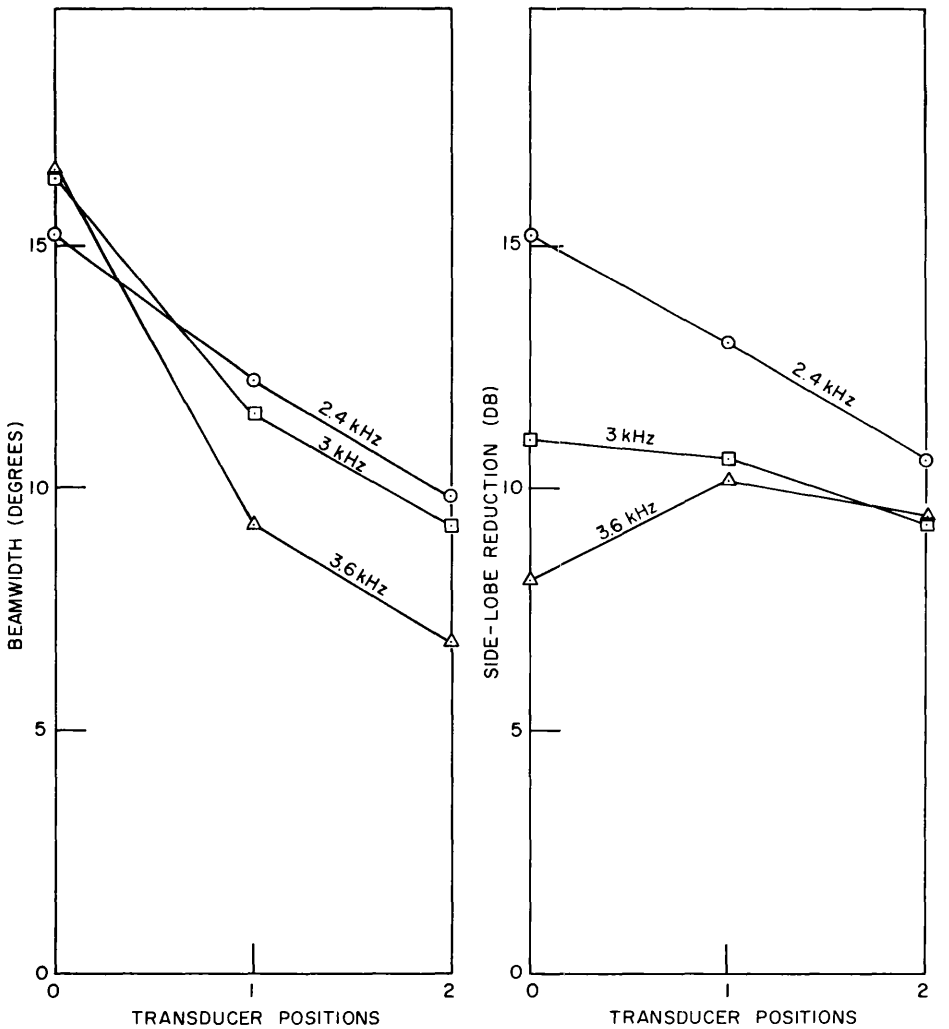

Fig. 7 - Transducer position effect on (a) beamwidth and (b) side-lobe reduction, using a conical reflector without a front baffle

Relatively soft foam-rubber backing appears suitable for depths to at least 90 ft.

Though secondary reflectors have been used by others, testing indicated herein shows them to add no appreciable improvement to source performance.

Lastly, extending the aperture of a given paraboloid to attain greater side-lobe reduction appears advisable up to about 30 to 34 degrees for the configuration tested.

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